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TECHNICAL REPORT

ADS - 5

OZONE MEASUREMENT SURVEY IN COMMERCIAL JET AIRCRAFT

by

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Under Contract ARDS-608

[redacted]

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SUMMARY

The purpose of this survey was (1) to accurately measure ozone concentration in commercial jet aircraft cabins and/or flight crew compartments on flights above 25,000 feet, in order to obtain a 12-month statistical evaluation, with emphasis on seasonal and meteorological correlations; and (2) to locate and chart the ozone-enriched air masses in order to obtain further meteorological correlations and to establish any abnormal conditions which result in exposure to large ozone concentrations.

Between September 1, 1962, and August 31, 1963, the ozone concentration in aircraft was measured during 295 commercial jet flights. These flights ranged over all segments of the United States and also included sections of Canada and the North Atlantic. All types of commercial jet aircraft currently employed by air carriers were monitored.

The ozone measurements recorded on each flight were evaluated. All the flights are tabulated in chronological order in the Appendix. The report includes summary tables of the data for the middle and northern latitudes. The data are also correlated graphically to show seasonal variations. The

maximum continuous ozone exposure encountered on a domestic flight was 20 or more parts per hundred million by volume for 140 minutes; the maximum on a northern flight was between 20 and 30 PPHM for four hours; the highest concentration encountered was 35 to 40 PPHM for 20 minutes. The most significant finding was that little or no ozone was detected on flights made below the tropopause. At or above the tropopause the internal concentration was usually above 5 PPHM, and in most cases above 10 PPHM.

OZONE MEASUREMENT SURVEY IN COMMERCIAL JET AIRCRAFT

I. INTRODUCTION

Shortly after commercial jet aircraft were placed in operation on regular flight schedules, many passengers reported that the odor of ozone was detectable in the fuselage from time to time. It was doubtful that the ozone was being generated inside the aircraft. However, since air entering the aircraft was required to pass through a compression cycle which raised the temperature to 250°F, ozone, being thermally unstable, could be expected to decompose at this temperature. Equally curious was the fact that ozone was encountered at altitudes of 30,000 to 40,000 feet, whereas the ozone layer of the atmosphere was generally considered to exist at 80,000 feet.

The toxicity and the physiological effects of ozone at certain concentration levels have been reported in the literature, and the reactivity of ozone with certain polymeric materials is also documented.

In December 1961, under the sponsorship of the Federal Aviation Agency, a 4-month study (Contract No. FA2688) was initiated at IIT Research Institute. The purpose was to determine the frequency and the concentration of ozone in commercial jet aircraft.

This study was made on 38 separate flights on the commercial routes of Airline "A". It covered the northern and central portions of the United States from New York to California and included five flights between California and Hawaii. The flights lasted from 60 to 325 minutes and covered altitudes from 9,000 to 39,000 feet. Ozone ranging in concentration from 1 to 22 parts per hundred million (PPHM) was detected during 50% of the total flight time.

On the basis of these preliminary results, the Federal Aviation Agency continued the study for a one-year period (Contract No. ARDS-608) and broadened the scope to include as many types of aircraft and flight patterns as possible. Seven major airlines cooperated by providing free air transportation for the research personnel who were responsible for the ozone measurements. The coast-to-coast routes were covered by flights operated by Airlines "C", "B", and "A"; the southern portion of the United States was covered by Airlines "D" and "C"; the northern latitudes were covered by Airline "E" polar route to London, Airline "F" route to Alaska, and Airline "G" route to Copenhagen. All types of U.S. type certificated jet transport category aircraft were used. The ultimate objective was to correlate the frequency and the concentration of ozone with geographic locations, meteorological conditions, flight patterns, altitudes, and types of aircraft.

II. MEASURING TECHNIQUES

The ozone analyzers used were selected from several commercially available types. The analyzer is based on the microcoulomb ozone sensor conceived by Dr. A. W. Brewer of Oxford University. The basic principle of this sensor is the well-known oxidation-reduction of potassium iodide, which is contained in the sensing solution. Two reactions take place in the sensor: oxidation of potassium iodide by ozone, and reduction of the released iodine by hydrogen. These electrochemical reactions take place at polarized electrodes which are immersed in the sensing solution. The measurement of electron flow or current through the external circuit is directly proportional to the mass of ozone entering the sensor per unit time. A constant-volume solution pump, a constant-volume sample pump, and a calibrated, electronic read-out system complete the instrument package.

The first analyzer used in this study was obtained in 1960 and was calibrated regularly in our laboratories by comparison with the standard wet analytical method in which sodium thiosulfate is used to titrate a buffered potassium iodide solution. This analyzer was also found to agree with instruments of other manufacturers. However, because it requires a 110-volt, a.c. power supply, certain modifications and auxiliary equipment were necessary before it could be operated in an aircraft.

Two additional analyzers were purchased when the scope of the program was broadened. These instruments are powered by rechargeable batteries, are more compact and hence less conspicuous, and are considerably more convenient to handle. The calibration of these instruments was regularly checked at 25-hour intervals against laboratory established ozone concentrations of 2, 8, 16, and 40 PPHM. Additional checks were made when unusual data were recorded. If the instruments did not agree to within 5% of the laboratory value, the previous data were discarded. The calibration was also checked for operation at the subatmospheric pressures found in jets. However, because of aircraft vibrations, slight temperature and pressure fluctuations, and the instruments' response time, the concentrations recorded during flights can be considered accurate only to within 10%.

At the start of the program it was considered advisable to attract the least possible attention from passengers. Consequently, the analyzer was generally placed in the cockpit and started in operation before the passengers boarded the aircraft. The engineer monitoring the analyzer usually rode the observer's seat in the cockpit. His duties were primarily to record pertinent flight data such as altitude and flight path and periodically check the operation of the analyzer.

Since the analyzer was operated in the cockpit, it was necessary to know whether the ozone concentration in the cockpit was the same as that in the main cabin. The air is changed every 3 minutes in the cabin, and every 1-1/2 minutes in the cockpit. It was also necessary to know whether the ozone content of the fresh incoming air differed from that of the air about to be exhausted and whether the air circulation in the aircraft was sufficient to eliminate any stagnant areas.

It was imperative that his information be gained early in the program. Because of cockpit space limitations, it was desirable to monitor some flights with the analyzer positioned in the cabin. Any relationship between ozone content and instrument location had to be determined before the data were evaluated.

Several flights with two or more analyzers aboard the same aircraft were necessary to answer these questions. The ozone content of the air was found to fluctuate rapidly; the concentration could double, or halve, in a matter of several minutes. This knowledge precluded the use of one instrument which could be moved to different locations in the aircraft. The incoming air could be analyzed by an instrument placed a few inches away from the auxiliary ventilating system, or "eyeball." The general level of ozone and the exhaust air could be analyzed by an instrument placed on the flight deck of the aircraft. Further checks could be made by turning the eyeball on and off.

This technique was very successful in establishing standards in the Type "M" and "Q" jets. Both these aircraft have eyeballs in the flight deck located adjacent to a convenient instrument position. The Type "O" jets do not have as convenient a testing location; but since these jets have a faster air turnover rate, it was believed that the results would be comparable.

Comparison of the ozone content of the flight deck with that of the main cabin was accomplished simply by using two analyzers. The second instrument was placed in the cabin before the passengers boarded the aircraft. Not too many tests were required to establish the fact that the ozone content was generally consistent throughout the aircraft. The slower air turnover in the cabin tended to dampen fluctuations, but the average values were the same as those measured in the flight deck. The incoming air, of course, showed the widest fluctuations; but its average value was, for all practical purposes, the same as the others. No areas of stagnation were located, even though sections of the after-cabin occasionally showed a temperature differential of 5 °F or more. Smoke, particularly from cigars or pipes, could temporarily reduce the ozone content immediately adjacent to the smoker by as much as 10%. It was also noted that the ozone level adjacent to the galley could drop about 10% during periods when food was being prepared. Even though these variations in ozone content could be considered minor and within normal fluctuations, the

majority of the measurements were made in the cockpit, with the instrument located close to an incoming airstream.

III. RESULTS AND DISCUSSION

A. Source of Ozone

The source of ozone is the external air. This fact is readily apparent from examination of the recordings. Operation of the analyzer for periods of up to one hour before takeoff but with all aircraft equipment operating established the base or zero level for each flight. During many flights, no ozone was detected for various periods of time. As a general rule, no ozone was detected below 25,000 feet, although a few exceptions were noted. For example, ozone was recorded at an altitude of several thousand feet over the Los Angeles smog basin and in areas adjacent to thunderstorms.

B. Differences among Aircraft

It was not possible to determine which type of aircraft would contain more ozone when traveling through a high external concentration. This is apparent from a study of the pressurization system and from data obtained on parallel flights.

The design characteristics of various aircraft pressurization systems was investigated. Specifications for each type of aircraft vary. In addition, further modifications are encountered in the same basic type of aircraft according to the preferences of a particular airline. Table 1 shows that the

pressurization systems differ with respect to compression temperatures and time periods at these temperatures. At first glance it appears that correlation of these factors with internal ozone concentration would give an ozone decomposing factor for each type of aircraft. This factor, in turn, could be used to calculate the ozone concentration of the outside air. Unfortunately, the actual operation of these various pressurization systems precludes any correlation.

When an aircraft cruises at high altitudes, some of the heat of compression is removed from the incoming air to control the internal cabin temperature. All the aircraft have two-stage refrigeration systems similar to the schematic illustration in Figure 1. In addition to the heat removed by the refrigeration system, considerable heat is also removed by conduction and radiation from the ductwork of the ventilating system. During the majority of flights, the primary cooler is regulated to control the cabin temperature. This is accomplished simply and economically by cooling only a portion of the incoming air. The bypassed hot air is mixed with the cooled air to produce the desired temperature in the cabin. This control is easily automated and rapidly corrects for fluctuations in the temperature of the external air, which often varies by 20°F in a matter of minutes.

The secondary refrigeration unit is not required unless the passenger loading is high, the outside temperature is higher than normal, or the flight personnel prefer a cooler cabin. Daytime flights, because of the additional heat supplied by the sun, require more cooling than nighttime flights. Other variables are changes in the outside temperature with altitude and changes in the barometric pressure during the course of a flight. One last feature that eliminates any possibility that internal ozone concentration can be correlated with the pressurization systems is the fact that the aircraft are operated by personnel who have individual preferences. Some crews prefer a warm cabin, some a cool cabin. Some maintain a smaller differential between the inside and outside pressure than others. Some crews anticipate altitude changes and maintain a constant pressure throughout a flight. Sometimes the cabin is cooled a little more during meal times. These differences preclude any calculation of the time that the incoming air is retained in the hot zone during an entire flight.

Numerous attempts were made to determine the relative effectiveness of the various pressurization systems in decomposing ozone. For example, the data listed in Table 2 were obtained on parallel flights between Seattle and Chicago on April 9, 1963. An "N" jet made the flight at 37,000 ft., followed 45 minutes later by a "Q" jet at 33,000 and 37,000 ft.

The pressurization systems of both aircraft were operating in a normal manner, i.e., with part of the incoming air bypassing the primary cooler. Evaluation of these data and comparisons between the data obtained on similar parallel flights (Figures 2 and 3) led to the conclusion that there is no significant difference in ozone-decomposing efficiency among the various types of aircraft.

C. Ozone Measurements

During the period from September 1, 1962, through August 31, 1963, the ozone concentration was monitored on 285 flights, which ranged from short (e.g., Chicago to New York) to medium (e.g., Chicago to San Francisco) to long (e.g., transcontinental, London to San Francisco). The average domestic flight lasted 3-1/4 hours; transcontinental flights over the northern latitudes averaged 7-1/2 hours. The flights were chosen at random, the only controls being to have at least two flights per week and to cover as large an area as possible. During the spring months the number of flights was increased to 6 or 8 per week.

The record for a typical domestic flight is shown in Figure 4. This trace shows that a substantial ozone concentration was encountered shortly after the aircraft reached cruising altitude. As the flight continued westward, the ozone concentration increased and then quite suddenly dropped to zero. No ozone was encountered over the plains states. Then another region of appreciable ozone was encountered. Fifteen minutes before the aircraft started to

descend, the ozone level again dropped to zero. From takeoff to landing, this particular flight lasted 5 hours and 22 minutes, 4 hours and 41 minutes of which were spent at the cruising altitude of 35,000 feet. Ozone in excess of 3 PPHM was encountered for 2-1/2 hours, or 46% of the total flight time. Ozone in excess of 5 PPHM was encountered for 2-1/4 hours, or 42% of the total flight time.

All the flights were evaluated in this manner. An example of a northern flight is presented in Figure 5. The data, assembled in monthly groups, are summarized in Tables 3, 4, and 5. A chronological listing is given in the Appendix. Also included in the Appendix are the data obtained from December 19, 1961, through April 30, 1962, on Contract No. FA 2688.

Examination of the individual flights shows that no ozone was recorded during some of them, whereas appreciable quantities were detected during others. With respect to domestic flights, the highest concentration of ozone detected for the longest period of time occurred in April 1963 on a flight from Seattle to Chicago, when the concentration exceeded 20 PPHM for the entire 140-minute period that the plane was at cruising altitude, 37,000 ft. With respect to the northern latitudes, the highest concentration detected for the longest period also occurred in April 1963, on a flight from London to Seattle, when the concentration fluctuated between 20 and 30 PPHM for 4 hours. The highest

concentration detected during any of the flights occurred in March 1963 on a flight from Anchorage to New York, when a concentration of 35 to 40 PPHM was recorded for a 20-minute period. The concentration was above 30 PPHM for 1 hour before the maximum concentration was recorded.

The expected seasonal variations are quite evident when the data are presented graphically, as in Figures 6 and 7. How the ozone level detected over the middle latitudes differs from that detected over the northern latitudes is clearly shown in the figures.

The ozone data can also be compared with the altitude data. As expected, the frequency and the concentration of ozone generally increases as the flight altitude increases. However, rather than the absolute altitude, the altitude of the tropopause appears to be the deciding factor. Figure 8 is a profile of meteorological conditions which existed during the flight illustrated in Figure 4. When the two figures are combined in Figure 9, it is obvious that ozone is encountered above the tropopause. Very seldom is ozone detectable below the tropopause. Further correlations of the quantity of ozone with height above the tropopause, with variations in latitude, and with seasonal variations are lengthy and complicated. The Meteorology Department of Airline "A" is studying the data for significant trends.

D. Internal and External Ozone Concentrations

No correlation has yet been established between internal and external ozone concentrations. During the latter months of the program, attempts were made to determine whether a constant relationship exists between the ozone concentration inside and outside the aircraft. This problem proved to be more difficult than expected. The data obtained to date are too sparse to provide an adequate correlation.

An approximation is available through comparison with data obtained by the Air Force on the Ozonesonde program. This comparison indicates that the aircraft pressurization system efficiently destroys low concentrations of ozone, but the efficiency decreases as the concentration of ozone increases. In other words, if the external air contains 5 to 10 PPHM ozone, little or none of this ozone will reach the cabin. An external ozone concentration of 50 PPHM will introduce perhaps 10 to 15 PPHM into the cabin, and an external concentration of 75 PPHM might be sufficient to produce the 30 PPHM occasionally recorded in the cabin. This correlation is very tentative and is based on readings from two different types of analyzers. The correlation should be narrowed by making controlled flights in the same area and at the same time as the Ozonesonde balloon ascents, with instrumentation that measures both the internal and the external ozone concentration.

IV. CONCLUSIONS

The principal objectives of the program were attained. The average and the maximum exposures of flight personnel and passengers to ozone were determined.

The ozone concentration varies with altitude, latitude, and season. The ozone-enriched air masses were located and identified as segments of the lower stratosphere. The altitude of the tropopause thus determines whether ozone will be detectable internally. The internal ozone concentration can be considered negligible (1 to 3 PPHM) on flights made below the tropopause. Fluctuations in the altitude of the tropopause are directly correlated with latitude and season.

Thus, only one factor need be determined in order to predict whether a significant concentration of ozone (5 PPHM or more) will be encountered on any projected flight. This one-variable correlation also allows extrapolation of the averaged data to specific routes. For example, those routes which are consistently flown above the tropopause, i.e., polar flights, will have a higher than average ozone exposure. Individual airlines can compare their flight patterns with tropopause data and obtain a better indication of the concentration of ozone likely to be encountered by their personnel. Unfortunately, time was not available to establish the relationship between ozone concentration and distance above the tropopause or seasonal variations in the height of the tropopause.

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APPENDIX - FIGURES AND TABLES

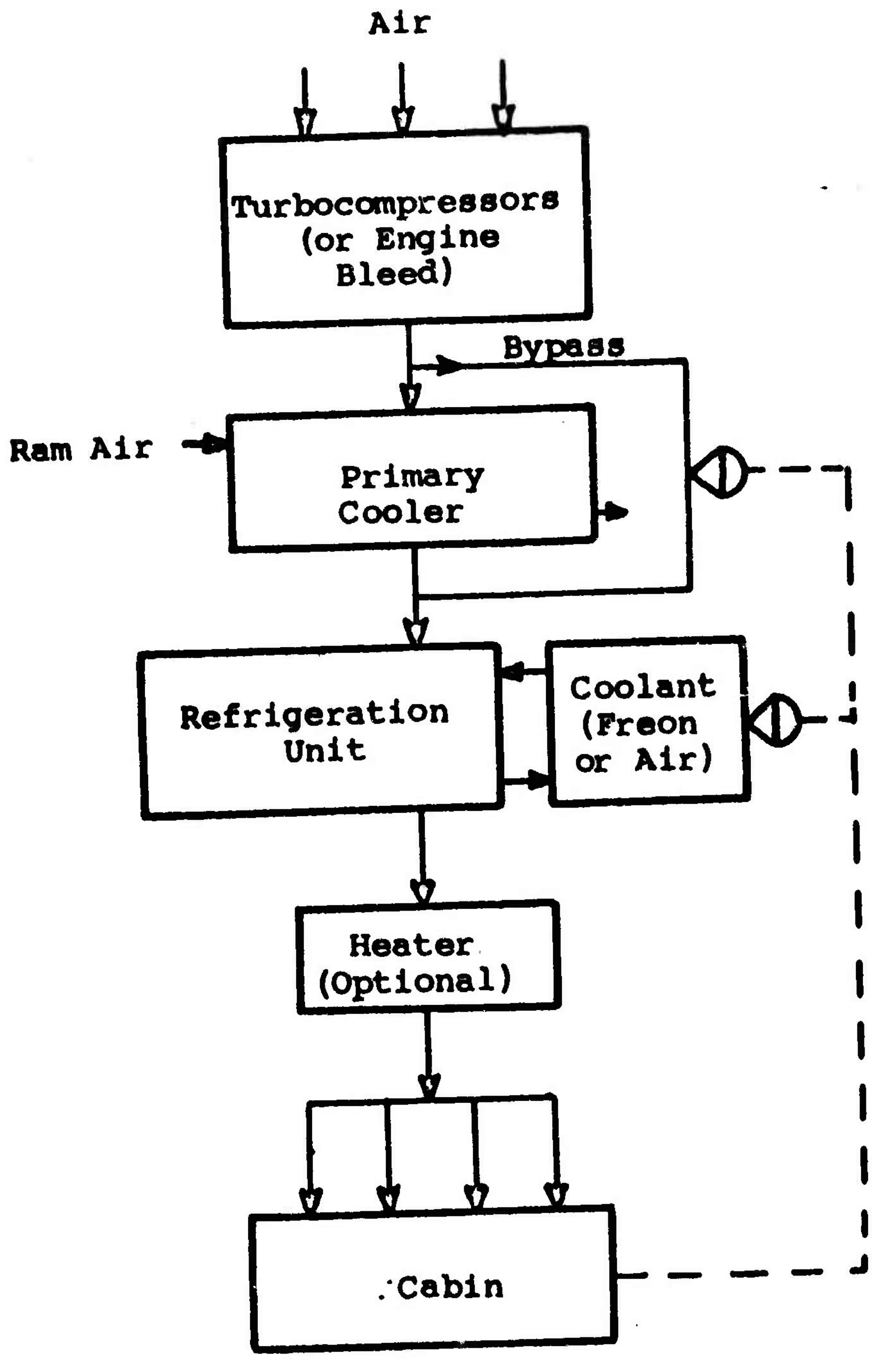


Figure 1

TWO-STAGE REFRIGERATION SYSTEM

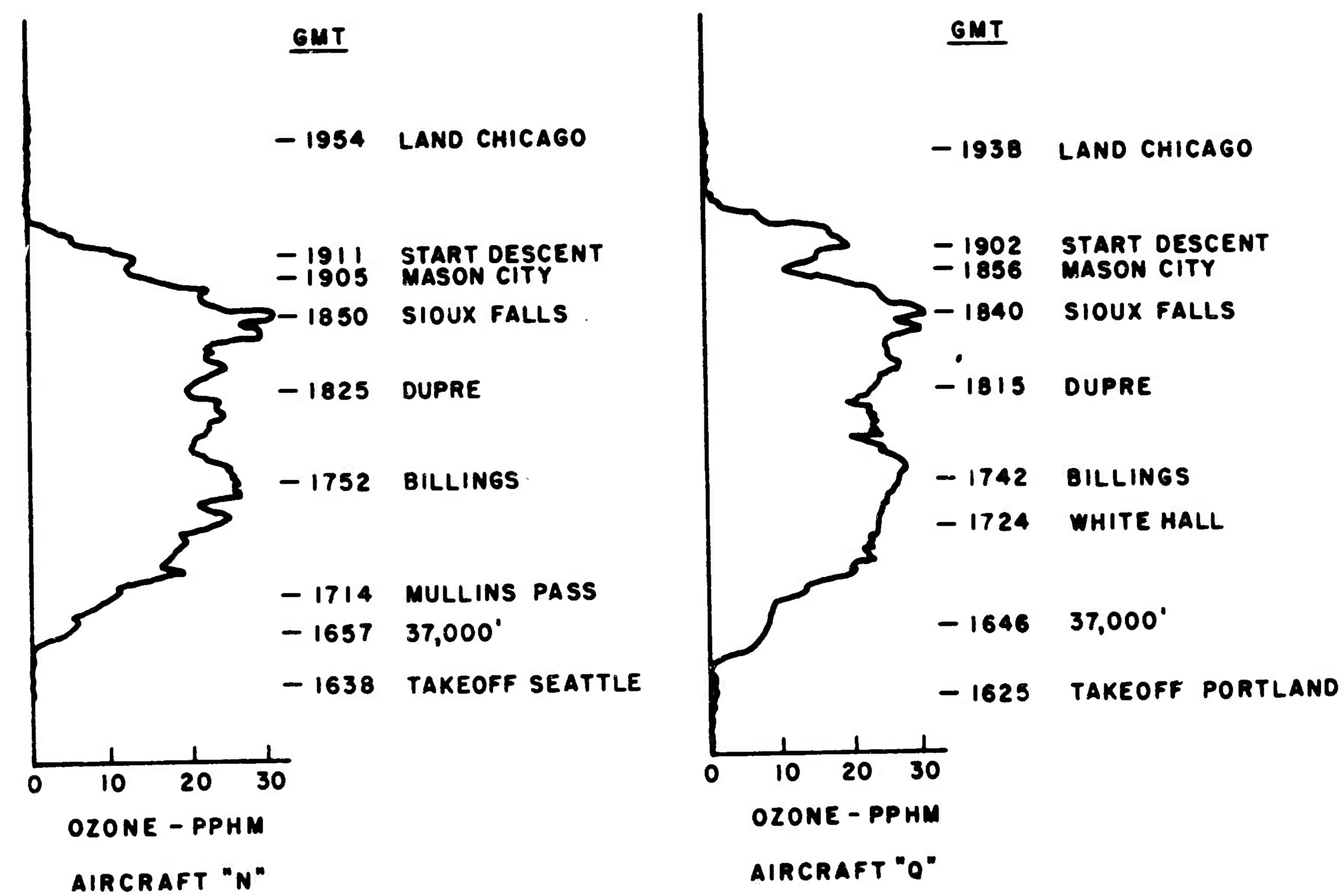
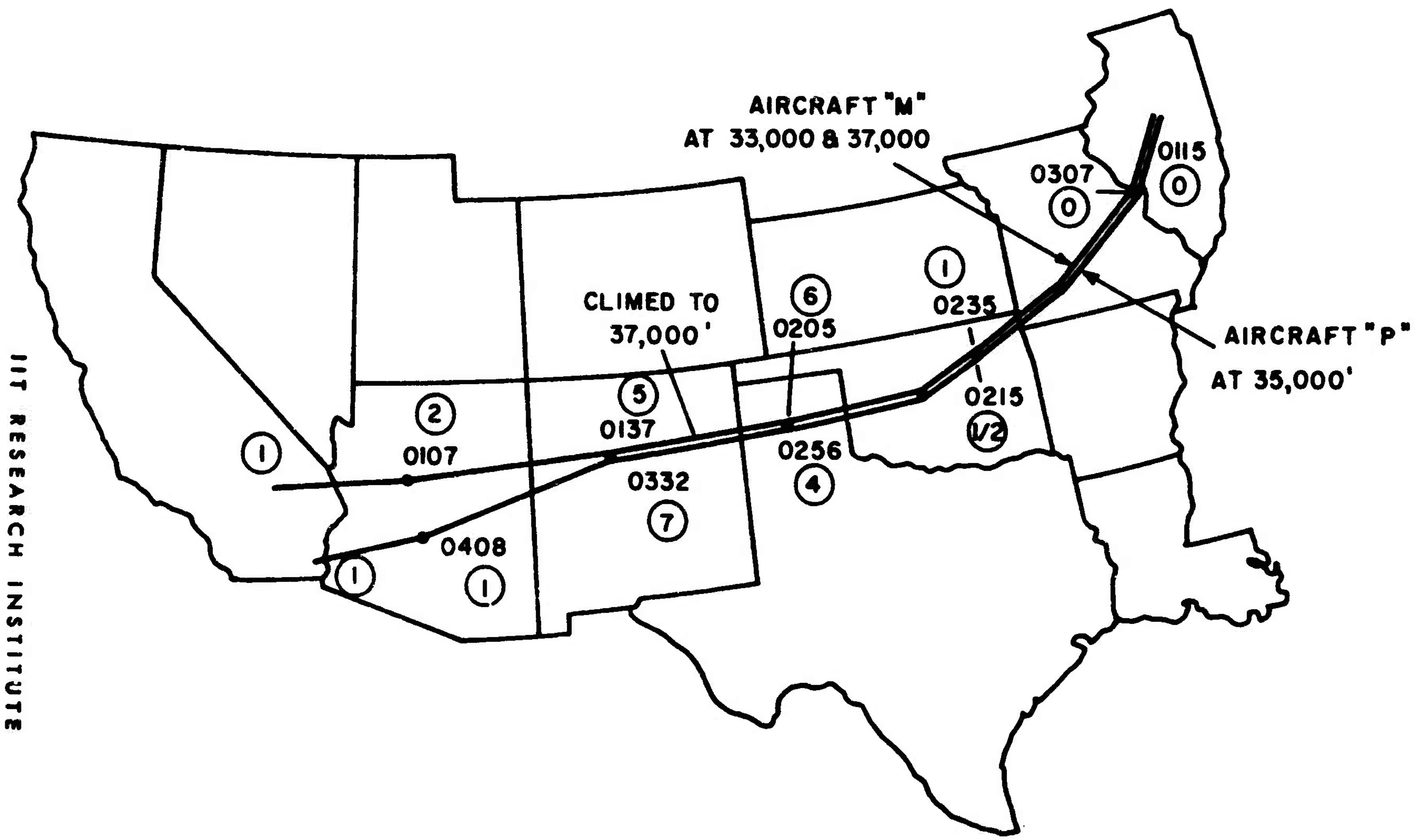


Figure 2

PARALLEL FLIGHTS MADE ON April 23, 1963



The numbers encircled are PPHM at the indicated Time over the check point

Figure 3

PARALLEL FLIGHTS MADE ON APRIL 28, 19[illegible]3

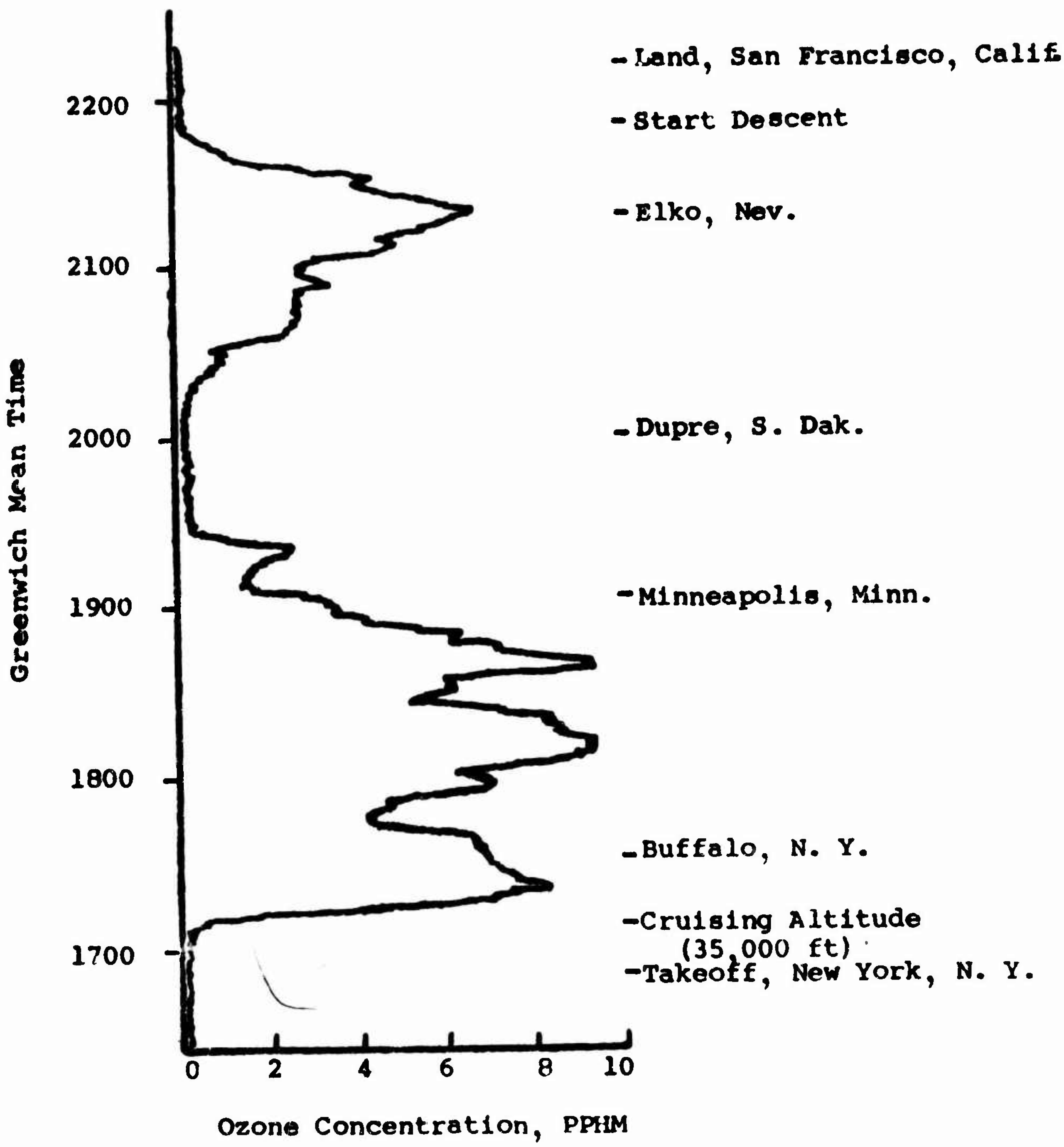


Figure 4

RECORD OF OZONE DETECTION
(New York to San Francisco, February 14, 1963)

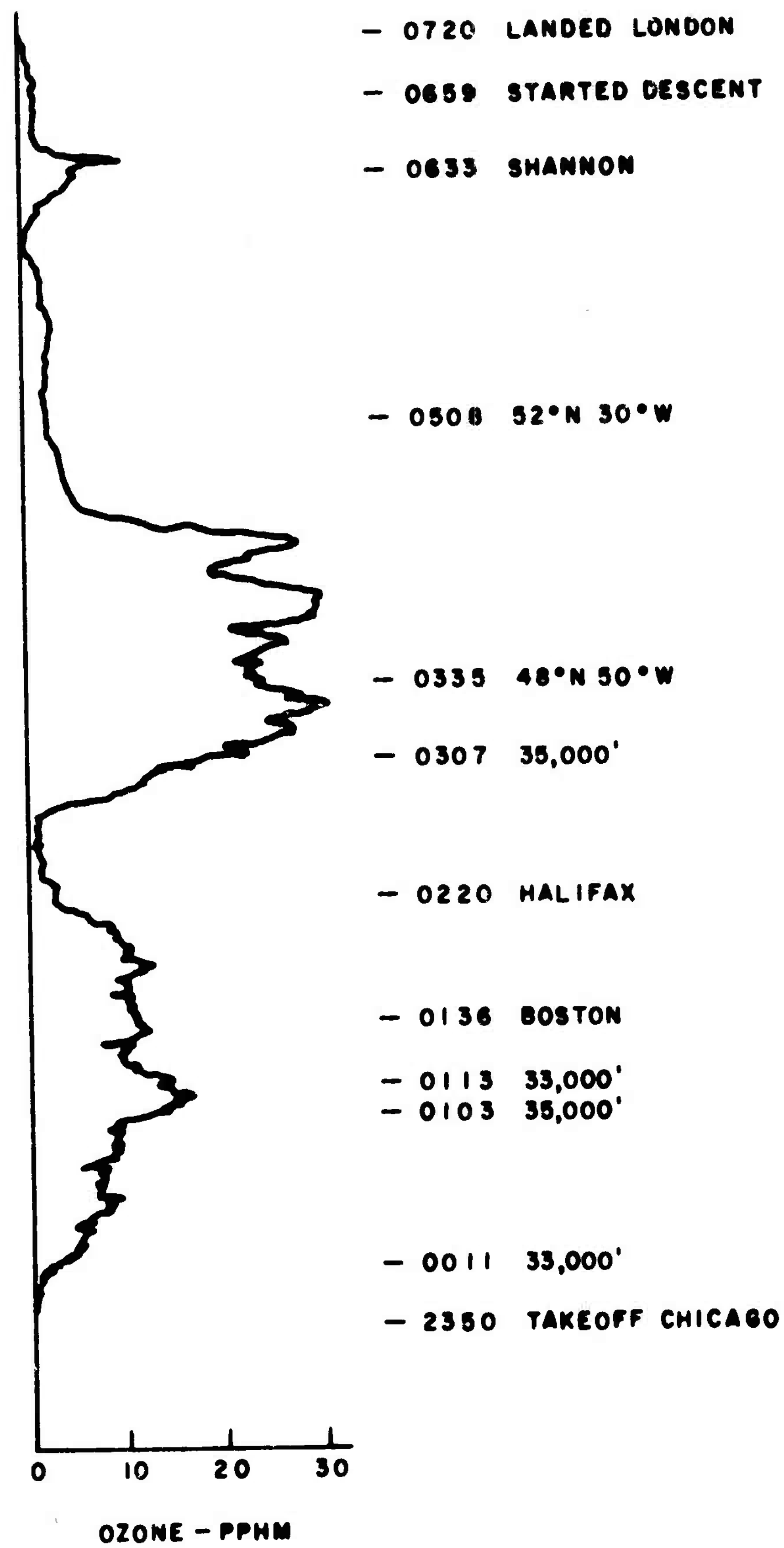


Figure 5

RECORD OF OZONE DETECTION
(NORTHERN ROUTES

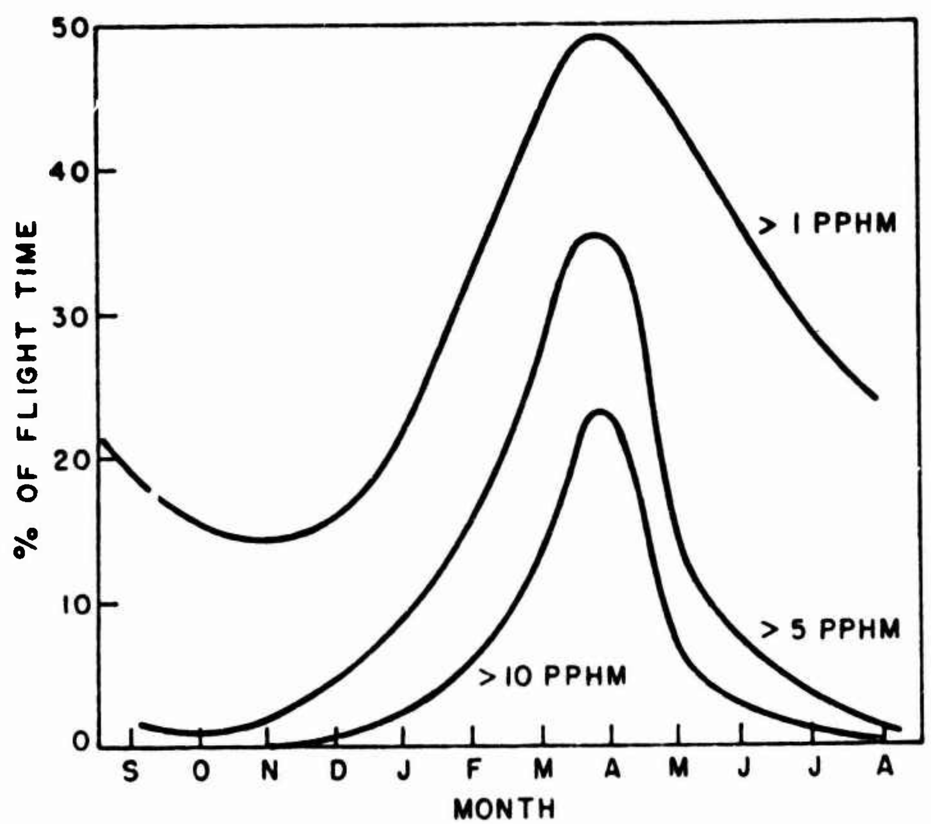


Figure 6

OZONE DETECTED DURING
FLIGHTS OVER MIDDLE LATITUDES

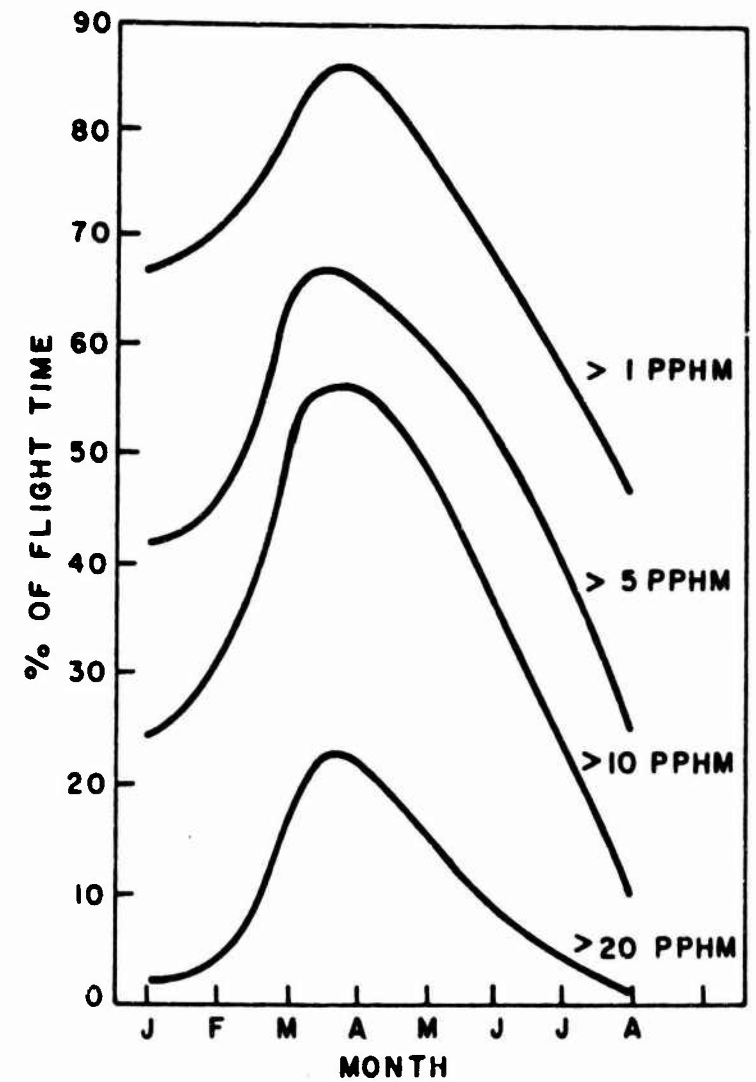
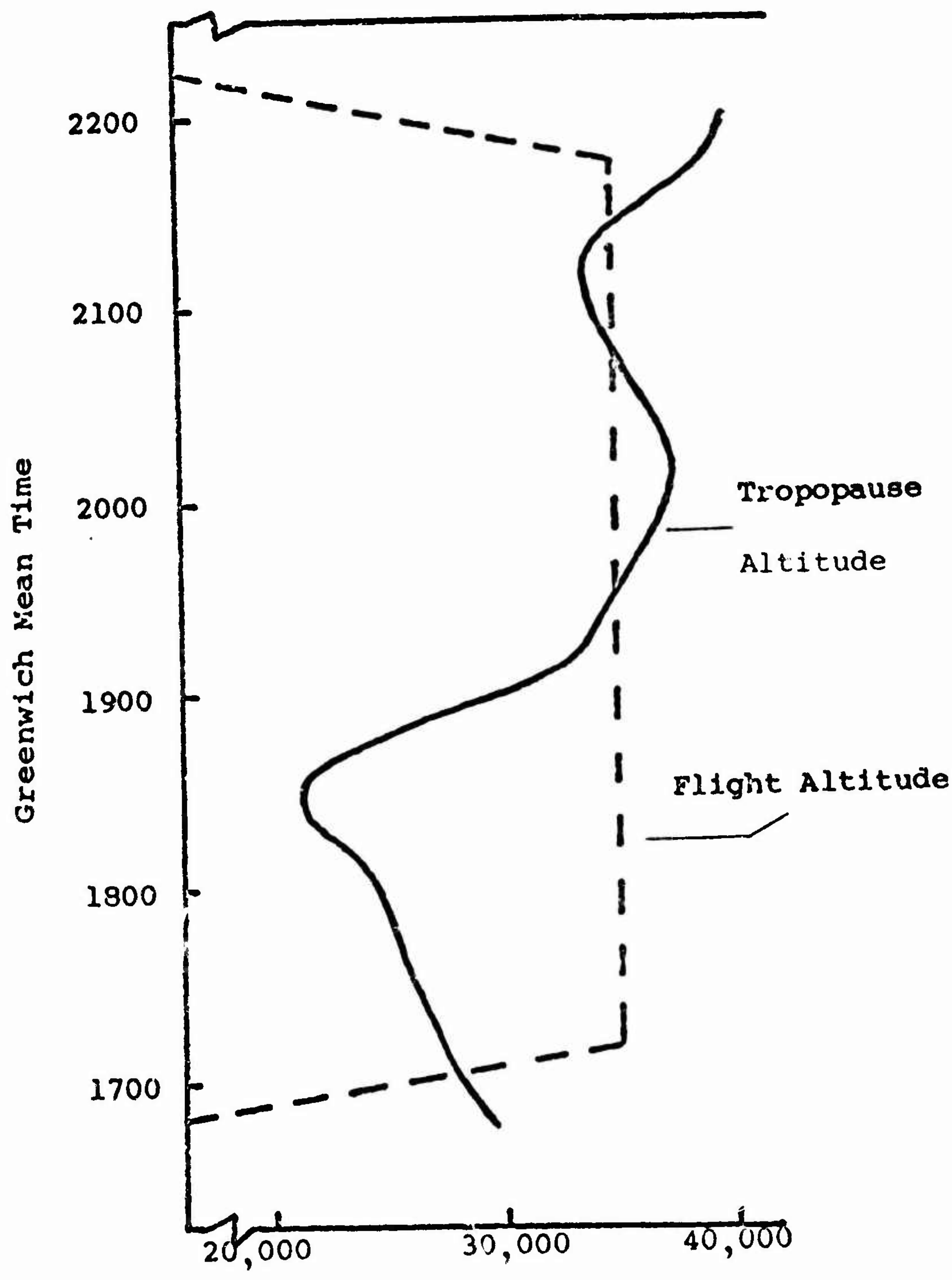


Figure 7

OZONE DETECTED DURING
FLIGHTS OVER NORTHERN LATITUDES



Altitude, ft.

Figure 8

PROFILE OF FLIGHT OF FEBRUARY 14, 1963,
AND TROPOPAUSE ALTITUDE

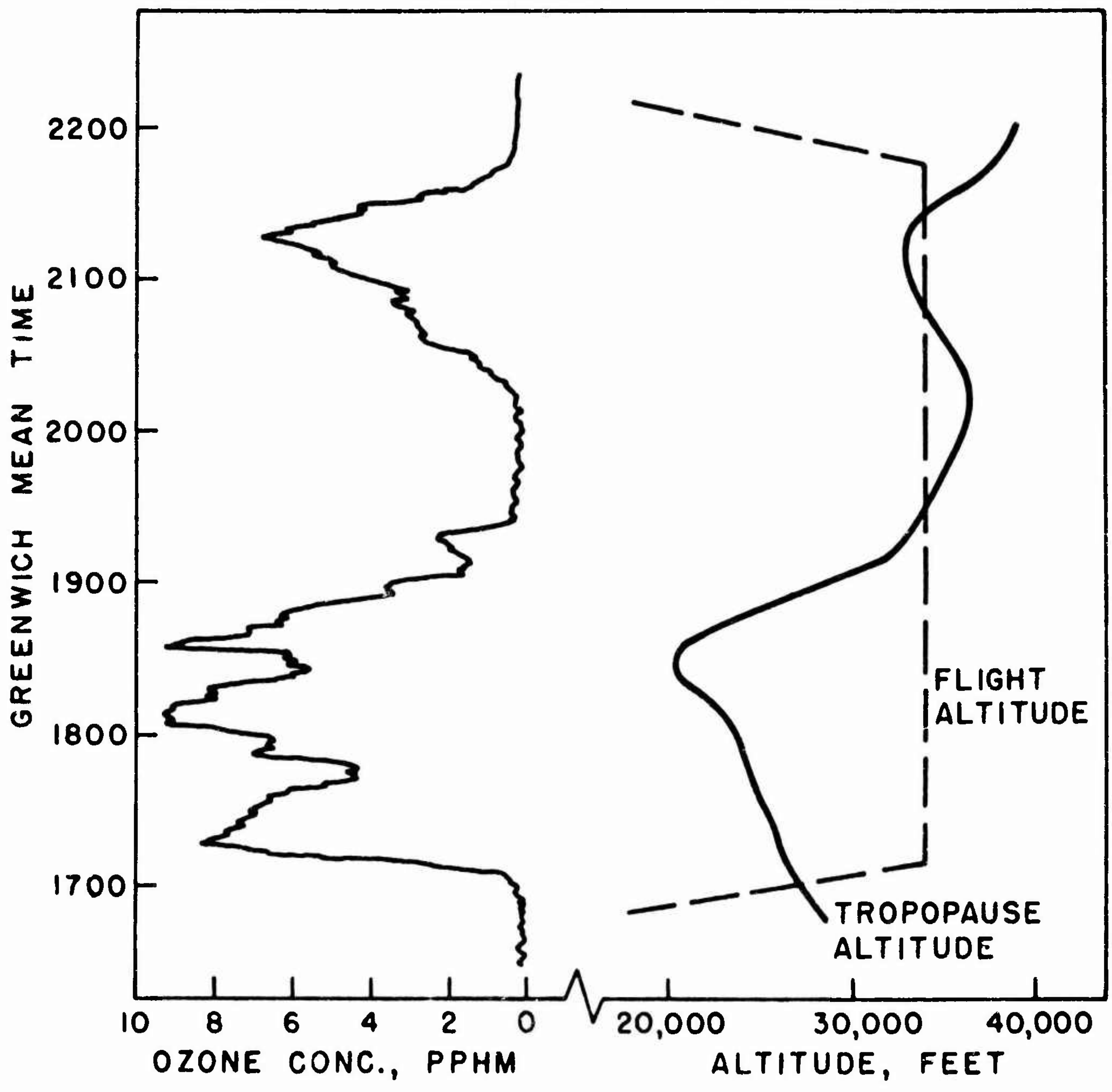


Figure 9

OZONE DETECTION AND TROPOPAUSE ALTITUDE

Table 1

NOMINAL COMPARISON OF AIRCRAFT PRESSURIZATION SYSTEMS

	Aircraft "M"	Aircraft "N"	Aircraft "O"	Aircraft "P"	Aircraft "Q"
Mode of pressurization: Normal / Alternate	Turbocompressor / Bleed air, 7th stage	Turbocompressor / Bleed air, 7th stage	Turbocompressor / Bleed air, 17th stage	Turbocompressor / Bleed air, 17th stage	Turbocompressor / None
Location of air inlet	Inboard engine pods	Inboard engine pods	Bottom of fuselage, forward of wings	Bottom of fuselage, forward of wings	Lower front of fuselage
Fuselage volume	9400 cu ft	8400 cu ft	4500 cu ft	5300 cu ft	9300 cu ft
Avg. time per air change: In flight deck / In cabin	1.5 min / 3 min	1.5 min / 3 min	1 min / 2 min	1.25 min / 2.5 min	1.5 min / 3 min
Volume of ductwork upstream of prime cooler	12 cu ft	12 cu ft	0.25 cu ft	0.25 cu ft	1.1 cu ft
Ductwork material	Type 321 SS	Type 321 SS	SS	SS	Aluminum
Airflow per turbocompressor at 35,000 ft	1600 cfm	1600 cfm	830 cfm	830 cfm	700 cfm
Pressure in duct at 35,000 ft	18 psia	18 psia	14 psia	14 psia	14 psia
Temperature in duct at 35,000 ft	250-275 °F	250-275 °F	290 °F	290 °F	200 °F
Residence time of air in hot zone	0.45 sec	0.45 sec	0.02 sec	0.02 sec	0.1 sec

Table 2

OZONE DETECTED ON TWO DIFFERENT AIRCRAFT DURING PARALLEL FLIGHTS BETWEEN SEATTLE AND CHICAGO ON APRIL 9, 1963

Check Point	Aircraft "N"		Aircraft "Q"	
	Altitude, ft	Ozone Conc., PPHM	Altitude, ft	Ozone Conc., PPHM
Spokane	37,000	14	33,000	5
Mullan Pass	37,000	8	33,000	8
Billings	37,000	10	33.000	10
Dupre	37,000	12	33,000	5
Sioux Falls	37,000	4	37,000	3
Mason City	37,000	5	37,000	3
Dubuque	37,000	5	37,000	5

Table 3

SUMMARY OF DATA ON OZONE DETECTION
DURING DOMESTIC FLIGHTS (MIDDLE LATITUDES)

Month	Number of Flights	Total Flight Time, min	Time above 25,000 ft, min	Time Ozone Detected, min							
				>1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
Sept 62	11	2269	1690 (74.5)*	513 (22.6)	153 (6.7)	73 (3.0)					
Oct 62	11	2257	1731 (76.7)	265 (11.7)	80 (3.6)	10 (0.4)					
Nov 62	17	3938	3002 (76.2)	1232 (31.4)	290 (7.4)	32 (0.8)					
Dec 62	13	2427	1787 (73.6)	745 (30.6)	235 (9.7)	150 (6.2)	25 (1.0)				
Jan 63	25	4566	3357 (73.5)	748 (16.4)	443 (9.7)	730 (8.1)	110 (2.4)	85 (1.8)	70 (1.5)	50 (1.1)	10 (0.2)
Feb 63	18	3168	2237 (70.6)	1048 (33.1)	810 (17.7)	610 (13.3)	250 (5.5)				
Mar 63	30	5840	4419 (75.6)	2569 (44.0)	1903 (32.5)	1554 (26.6)	785 (13.4)	275 (4.7)	35 (0.6)		
Apr 63	26	4758	3451 (72.5)	2396 (50.3)	1927 (40.5)	1715 (36.1)	1125 (23.7)	904 (19.0)	644 (13.5)	290 (6.1)	105 (2.2)
May 63	24	4689	3391 (72.3)	1712 (36.5)	871 (18.5)	650 (13.8)	198 (4.2)	70 (1.5)	15 (0.3)		
June 63	23	3660	2476 (67.0)	1194 (32.6)	370 (10.0)	287 (7.8)	110 (3.0)	40 (1.1)			
July 63	11	1655	1134 (68.4)	59[illegible] (35.9)	71 (4.3)	56 (3.4)	21 (1.2)				
Aug 63	19	3035	1897 (62.5)	610 (20.1)	30 (1.0)	5 (0.2)					

*Numbers in parentheses refer to percent of total flight time.

Table 4

SUMMARY OF DATA ON OZONE DETECTION
DURING FLIGHTS IN NORTHERN LATITUDES

Month	Number of Flights	Total Flight Time, min	Time above 25,000 ft, min	Time Ozone Detected, min							
				>1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
Jan 63	8	3628	3105 (85.5)*	2483 (63.4)	1904 (52.5)	1548 (47.7)	937 (25.8)	285 (7.8)	100 (2.7)	30 (0.8)	15 (0.4)
Feb 63	5	2544	2253 (88.6)	1761 (69.3)	1461 (57.5)	1131 (44.4)	601 (23.6)	260 (10.2)	85 (3.3)		
Mar 63	11	4666	4104 (88.1)	3697 (79.2)	3311 (71.2)	3151 (67.7)	2273 (48.8)	1433 (30.7)	744 (16.0)	454 (9.7)	175 (3.7)
Apr 63	6	3166	2833 (89.3)	2753 (87.0)	2341 (73.8)	2110 (66.7)	1804 (57.0)	1276 (40.3)	716 (22.5)	191 (6.0)	86 (2.7)
May 63	9	3441	2962 (86.2)	2632 (76.5)	1524 (44.3)	1419 (41.3)	1109 (32.3)	839 (24.4)	587 (17.0)	215 (6.2)	30 (0.9)
June 63	7	3374	2960 (87.7)	2105 (62.3)	1835 (54.3)	1735 (51.3)	1148 (34.0)	624 (18.5)	152 (4.5)		
July 63	4	1330	1113 (83.3)	796 (59.8)	604 (45.5)	589 (44.3)	481 (36.1)	302 (22.7)	95 (7.1)		
Aug 63	4	1271	1089 (8[illegible].3)	595 (46.8)	320 (25.2)	265 (20.8)	45 (3.5)				

*Numbers in parentheses refer to percent of total flight time.

Table 5

SUMMARY OF DATA ON OZONE DETECTION
DURING DOMESTIC FLIGHTS (MIDDLE LATITUDES) IN SPRING 1962

Month	Number of Flights	Total Flight Time, min	Time above 25,000 ft, min	Time Ozone Detected, min					
				>1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM
Feb	14	2880	2375 (82.5)*	930 (32.2)	380 (13.2)	270 (9.4)	185 (6.4)	5 (0.2)	
Mar	14	3095	2495 (80.7)	1885 (60.8)	595 (19.2)	390 (12.6)	115 (3.7)		
Apr	8	790	435 (55.1)	425 (53.8)	150 (19.0)	125 (15.8)	115 (15.1)	85 (10.7)	10 (1.2)

*Numbers in parentheses refer to percent of total flight time.

Table 6

CHRONOLOGICAL SUMMARY OF OZONE DETECTION DURING FLIGHTS OVER MIDDLE LATITUDES

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
9/17/62	Chicago	S. F.	D	232	28,000	31	5							
					31,000	163								
9/17/62	S. F.	Honolulu	D	286	28,000	139	15							
					31,000	94								
9/19/62	Honolulu	S. F.	N	270	33,000	215								
9/18/62	S. F.	Chicago	D	215	29,000	80								
					37,000	80	25							
9/27/62	Chicago	New York	D	103	37,000	15	15							
					39,000	33	5							
9/27/62	New York	S. F.	D	314	31,000	148	70	30	15					
					39,000	115	115	30	20					
9/28/62	New York	Chicago	D	105	31,000	18	18	18	13					
					35,000	30	30	30	25					
10/4/62	Chicago	New York	D	105	25,000	35								
					27,000	25	15							
10/4/62	New York	S. F.	D	308	28,000	73	60	15						
					31,000	143	45	15						
					35,000	45								
10/5/62	New York	Denver	D	202	28,000	7								
					31,000	158	50	15						
10/5/62	Denver	Chicago	D	129	25,000	18								
					29,000	10								
					31,000	15								
10/11/62	Chicago	New York	D	94	29,000	44								
10/11/62	New York	L. A.	D	315	28,000	262								
10/11/62	L. A.	Denver	N	100	27,000	68								
10/11/62	Denver	Chicago	N	105	29,000	34								
					31,000	35								
10/19/62	Chicago	S. F.	D	230	31,000	80								
					35,000	105	60							
10/19/62	S. F.	Honolulu	D	270	31,000	180								
					35,000	47								

Table 6 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
10/20/62	Honolulu	S. F.	N	273	31,000	225	40							
10/20/62	S. F.	Chicago	D	235	27,000	158								
10/25/62	Chicago	New York	D	92	29,000	47	45	20						
10/25/62	New York	S. F.	D	322	28,000	273	90	60	10					
10/26/62	S. F.	Chicago	D	221	27,000	173	30							
11/1/62	Chicago	New York	D	93	29,000	46	40							
11/1/62	New York	S. F.	D/N	317	35,000	165	165	25						
					39,000	103	25							
11/4/62	Chicago	Baltimore	D	105	29,000	45	35	10						
11/5/62	Baltimore	S. F.	N	313	31,000	264	30	5						
11/7/62	S. F.	Baltimore	D	275	29,000	118	35							
					33,000	103	103	43	25					
11/7/62	Baltimore	L. A.	N	301	31,000	165	120	35						
					35,000	67	67	57	7					
11/16/62	L. A.	Baltimore	D	247	33,000	47	45	15						
					37,000	140	120							
11/16/62	Baltimore	S. F.	N	320	28,000	100	30							
					31,000	140	130	55						
					35,000	22	22							
11/17/62	S. F.	Chicago	D	210	29,000	85	35							
					33,000	68	45	15						
11/20/62	Chicago	New York	D	88	39,000	33	30	20						
11/20/62	New York	S. F.	N	336	28,000	297	65							
11/21/62	S. F.	Chicago	D	207	29,000	35								
					33,000	31	5							
					37,000	87	65	10						
11/28/62	Chicago	New York	D	95	29,000	49								
11/28/62	New York	S. F.	N	335	28,000	257	10							
11/29/62	S. F.	Chicago	D	221	29,000	101	10							
					37,000	66								
11/30/62	Chicago	S. F.	D	225	28,000	30								
					31,000	145								

Table 6 (Cont.)

Date	Flight Route: Origin	Flight Route: Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min: >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
11/30/62	S. F.	Honolulu	D	250	31,000	13								
					35,000	95								
					39,000	85								
12/3/62	Honolulu	L. A.	D	290	29,000	245	180							
12/3/62	L. A.	Denver	N	130	27,000	120								
12/3/62	Denver	Chicago	N	120	29,000	70	50							
12/6/62	Chicago	Seattle	D	226	28,000	18[illegible]								
12/7/62	Seattle	Chicago	D	194	33,000	121	80							
12/10/62	Chicago	Seattle	D	245	28,000	115	60							
					31,000	88								
12/11/62	Seattle	Chicago	D	206	37,000	152	75	50	30					
12/19/62	Chicago	Las Vegas	D	188	31,000	151	5							
12/20/62	Las Vegas	Chicago	N	175	27,000	15								
					37,000	110	95	15						
12/21/62	Chicago	L. A.	N	212	35,000	39	20	20	10					
					39,000	121	120	120	95	25				
12/21/62	L. A.	Chicago	D/N	215	29,000	159								
12/27/62	Chicago	New York	D	108	25,000	26								
12/27/62	New York	Chicago	N	118	26,000	14	5							
					35,000	57	55	30	15					
1/3/63	Chicago	Seattle	N	260	31,000	25								
					35,000	165								
1/8/63	Chicago	L. A.	D	226	31,000	182								
1/10/63	Chicago	Mex. City	D	227	31,000	46								
					39,000	135	45	10						
1/10/63	Mex. City	Chicago	N	225	33,000	10								
					37,000	150	45	5						
1/11/63	L. A.	Chicago	D	192	29,000	133								
1/14/63	Chicago	Mex. City	D	217	25,000	92	75							
					31,000	89	35							

Table 6 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
1/15/63	Mex. City	Chicago	N	180	31,000	20								
					33,000	116	15							
1/17/63	Chicago	S. F.	D	233	24,000	59								
					29,000	10								
					31,000	128	20							
1/17/63	Chicago	S. F.	D	235	37,000	29								
					39,000	143	143	143	110					
1/17/63	S. F.	Devner	D	118	27,000	75								
1/17/63	Denver	Baltimore	N	158	37,000	110	75	65	55					
1/18/63	New York	Chicago	D	124	28,000	35								
					33,000	35								
1/21/63	Chicago	Denver	D	125	31,000	90								
1/21/63	Denver	Chicago	D	120	29,000	53								
1/23/63	L. A.	Chicago	N	187	33,000	47								
					37,000	95	60	15						
1/23/63	Chicago	Seattle	N	238	28,000	190	5							
1/24/63	Chicago	L. A.	N	220	31,000	189								
1/26/63	L. A.	Chicago	D	185	29,000	62								
					37,000	78	75	70	70	10				
1/29/63	Seattle	Chicago	N	180	37,000	140	135	135	135	100	85	70	50	10
1/29/63	Chicago	Phoenix	D	191	28,000	55								
					31,000	99								
1/29/63	Phoenix	Chicago	D/N	154	37,000	78								
1/31/63	Chicago	New Orl.	D	116	31,000	72								
1/31/63	New Orl.	Baltimore	N	112	33,000	67								
1/31/63	Chicago	Seattle	D	236	38,000	201	20							
1/31/63	Seattle	S. F.	D	107	33,000	54								

Table 6 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
2/1/63	S. F.	Chicago	N	193	33,000	127	40							
2/1/63	Wash.	Chicago	D	103	35,000	46								
2/8/63	Chicago	Boston	D	101	33,000	58	50	20	20					
2/8/63	Boston	Chicago	N	123	35,000 39,000	42 30	35 25	35 25	5 25					
2/10/63	Chicago	San Diego	N	222	28,000	183								
2/12/63	L. A.	Chicago	D	214	29,000 37,000	98 65	5 65	65	65	30				
2/14/63	Chicago	New York	D	88	37,000	42	42	5	5					
2/14/63	New York	S. F.	D	330	31,000	290	130	115	90	65				
2/14/63	New York	S. F.	D	322	35,000	281	195	150	135					
2/15/63	S. F.	Chicago	D	223	37,000	159	150	150	125	95				
2/22/63	Chicago	L. A.	D	220	33,000 39,000	42 125	25 125	15 95	15 95	60				
2/22/63	L. A.	Chicago	D/N	192	37,000	135								
2/23/63	Las Vegas	Chicago	N	172	28,000	137								
2/28/63	L. A.	Chicago	D	209	29,000 33,000	30 120								
2/28/63	Chicago	New York	D	91	33,000	36	20	15						
2/28/63	Chicago	Hartford	D	98	37,000	38	45	45	30					
2/28/63	New York	Chicago	D	117	28,000	72	15							
2/28/63	Hartford	Chicago	D/N	150	35,000	81	81	75						
3/1/63	Chicago	New Orl.	D	111	26,000	78								
3/2/63	New Orl.	Chicago	N	110	27,000	59								
3/4/63	Chicago	L. A.	D	205	31,000	167	25							
3/4/63	Chicago	L. A.	N	225	39,000	166	135	1 -	110	95				

Table 6 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
3/4/63	L.A.	New York	N	259	37,000	200	145	50	40	20				
3/5/63	New York	Chicago	D	115	39,000	50	50	35	25	25	10	10		
3/8/63	Chicago	L.A.	N	220	31,000	180								
3/8/63	L.A.	Chicago	D	193	37,000	130	130	130	95	15				
3/9/63	Chicago	Seattle	D	221	35,000 39,000	10 163	10 163	10 163	10 133	100	40	10		
3/11/63	Seattle	Chicago	D	201	37,000 39,000	57 93	57 93	57 93	57 93	57 93	32 93	10		
3/13/63	L.A.	Detroit	N	272	37,000	219	219	185	155	10				
3/16/63	New York	Chicago	D	128	35,000 28,000	50 22								
3/18/63	Chicago	Seattle	D	223	39,000	177	177	155	1[illegible]5	85	45	5		
3/18/63	Chicago	L.A.	D	219	35,000	173	120	90	75	15				
3/19/63	Seattle	Chicago	D	195	33,000 37,000	15 130	130	100	90	45	10			
3/19/63	L.A.	Chicago	N	198	37,000	146	146	146	136	15				
3/21/63	Chicago	S. F.	N	223	35,000 39,000	34 145	15 90	5 15						
3/22/63	S.F.	New York	D	271	29,000 37,000	134 112	55	40	40					
3/22/63	New York	Chicago	N	103	31,000	67	20							
3/22/63	Chicago	S. F.	D	230	31,000 35,000	126 47	10 45	10 35						
3/22/63	S. F.	Honolulu	N	285	[illegible],000	256	100	10						
3/24/63	Honolulu	S. F.	D	260	33,000 37,000	75 140	45	45	15					
3/25/63	S. F.	Chicago	D	202	37,000	153	80	70	55					
3/26/63	Chicago	Seattle	N	222	39,000	180	180	180	180	180	45			

Table 6 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
3/26/63	Chicago	New Orl.	D	107	31,000	65	25	15						
3/27/63	Seattle	Chicago	D	190	37,000	144	144	144	100	30				
3/28/63	New Orl.	Chicago	N	125	29,000	73	-							
3/28/63	Chicago	Portland	N	228	28,000	92	5							
					31,000	85	10	10	10					
3/30/63	New York	Chicago	N	105	28,000	53	45							
					31,000	16	10							
3/31/63	L. A.	Chicago	N	194	37,000	137	90							
4/1/63	Chicago	L. A.	D/N	230	28,000	177	30	25	20					
4/2/63	L. A.	Chicago	D/N	196	37,000	123	95	65	65	55	35	10		
					39,000	12	12	12	12					
4/2/63	Chicago	Spokane	D	200	39,000	145	145	145	120	95	85	70	25	
4/3/63	Seattle	Chicago	D	210	37,000	138	105	90	80	70				
4/5/63	Chicago	Seattle	D	232	39,000	170	170	90	15					
4/5/63	Portland	Honolulu	N	338	35,000	138	138	123	108					
					39,000	43	20							
					41,000	111								
4/9/63	Seattle	Chicago	D	179	37,000	134	134	115	100	35	15			
4/9/63	Seattle	Chicago	D	191	33,000	93	93	93	78	10				
					37,000	47	47	47	15					
4/10/63	Chicago	Miami	D	133	37,000	89	15							
4/10/63	Miami	Chicago	N	155	39,000	113	10							
4/15/63	Chicago	New York	D	95	37,000	18	18	18	13	6	6			
					41,000	27	27	27	27	27	12			
4/15/63	Chicago	New York	D	93	29,000	53								
4/15/63	New York	Minneapolis	N	144	39,000	93	70	55	55	45	35	5		
4/15/63	Minneapolis	Chicago	N	58	33,000	5								

Table 6 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min ≥½ PPHM	≥1 PPHM	≥5 PPHM	≥10 PPHM	≥15 PPHM	≥20 PPHM	≥25 PPHM	≥30 PPHM
4/17/63	Chicago	L. A.	D/N	237	28,000	200	185	85	70	30	20			
4/18/63	L. A.	Chicago	D/N	208	37,000	145	145	135	135	120	110	75	20	-
4/19/63	Chicago	Baltimore	D	73	37,000	28	5							
4/19/63	Baltimore	Chicago	N	106	28,000 35,000	10 44	 35	 20	 20					
4/22/63	Chicago	Seattle	D	220	39,000	178	145	145	145	115	105	75	25	
4/22/63	Chicago	Portland	N	222	31,000 35,000	68 117	45 117	35 117	35 117	 117	 117	 70		
4/23/63	Portland	Chicago	D	193	37,000	136	136	136	136	136	125	110	35	15
4/23/63	Seattle	Chicago	D	196	37,000	134	134	134	134	119	99	89	30	
4/23/63	Seattle	Chicago	D	199	37,000	140	140	140	140	140	140	140	70	70
4/28/63	L. A.	Chicago	N	191	33,000 3[illegible],000	64 86	40 30	15 15	15 15					
4/28/63	Chicago	San Diego	N	241	[illegible],000 39,000	175 17	100	45	45	5				
4/30/63	Chicago	S. F.	N	218	31,000	180	10							
5/1/63	S. F.	Chicago	D	211	37,000	154	100	85	50					
5/1/63	Las Vegas	Chicago	D	171	37,000 39,000	31 87	31 87	31 87	25 87	 35				
5/4/63	Chicago	Mex. City	D	197	39,000	125	[illegible]							
5/4/63	Mex. City	Chicago	D	201	33,000 37,000 39,000	51 59 40	15 15							
5/7/63	Chicago	L. A.	D	220	35,000 39,000	93 69								
5/8/63	L. A.	Chicago	D/N	209	37,000	144	5							

Table 6 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
5/10/63	Seattle	Chicago	D	200	33,000	129	60	30	25	15	10			
5/10/63	Chicago	Mex. City	D	199	31,000	156								
5/11/63	Mex. City	Chicago	D	193	37,000	146	5							
5/13/63	Chicago	S. F.	D/N	234	28,000	131								
					31,000	23								
					33,000	30	30	15	15					
5/14/63	S. F.	New York	D	277	33,000	69	65	60	40	5				
					37,000	155	65	60	55	35				
5/14/63	New York	Chicago	D	109	28,000	70	10							
5/15/63	Chicago	Seattle	D	220	39,000	173	160	125	115	75	50	15		
5/19/63	Chicago	Baltimore	D	75	37,000	11								
					41,000	18	18	18	18	13				
5/21/63	Chicago	Baltimore	D/N	75	29,000	33	33							
5/21/63	Baltimore	L. A.	D	289	31,000	245	50	20						
5/22/63	L. A.	Chicago	D	194	37,000	37								
					39,000	93	60	50	25	15	10			
5/22/63	Washington	L. A.	D	293	28,000	255	205	65	35					
5/23/63	Portland	S. F.	D	80	27,000	40	10							
5/23/63	Chicago	L. A.	D	230	35,000	170	170	35	35					
5/24/63	L. A.	Chicago	D	195	33,000	100	90							
					37,000	15	15	10						
3/24/63	L. A.	Chicago	N	192	37,000	126	126	20	20	5				
					33,000	17	17							
5/28/63	Chicago	L. A.	D	219	39,000	161	140	90	65					
5/28/63	L. A.	Chicago	D	206	37,000	135	100	70	40					
6/5/63	Chicago	Baltimore	D	82	33,000	37	30	20	15					
6/5/63	Baltimore	Chicago	D	90	31,000	36	36	5	5					
6/7/63	Chicago	Dallas	D	94	28,000	42								

Table 6 (Cont.)

Date	Flight Rate: Origin	Flight Rate: Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min: >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
6/7/63	Dallas	Orlando	D	127	24,000	22	22							
					37,000	63	63	13						
6/9/63	L. A.	Chicago	D/N	189	37,000	136	90	40	30	15				
6/10/63	Tampa	Chicago	D	122	31,000	85								
6/12/63	Chicago	Seattle	D	230	28,000	40								
					31,000	139	30							
6/12/63	Seattle	New York	N	252	37,000	135								
					41,000	61	61							
6/13/63	New York	Chicago	D	106	28,000	62	35							
6/13/63	Chicago	Seattle	D	228	28,000	197	65							
6/13/63	Chicago	Baltimore	D	85	33,000	35	15							
6/13/63	Baltimore	Chicago	D	91	31,000	17								
					35,000	19								
6/15/63	Portland	Chicago	D	195	37,000	107	100							
					39,000	44	44	44	24					
6/19/63	Chicago	L. A.	D	216	31,000	48	40	15						
					35,000	119	85	30	30	20				
6/21/63	S. F.	New York	D	280	33,000	44	25	15	15					
					37,000	185	155	95	95	55	40			
6/21/63	New York	Chicago	D	110	31,000	27	15							
					35,000	33	33	33	33					
6/21/63	Las Vegas	Chicago	D	166	33,000	122	105							
6/21/63	L. A.	Omaha	D	152	37,000	108	45	20						
6/23/63	Chicago	New York	D	112	37,000	12	12	12	12					
					41,000	28	28	28	28	20				
6/24/63	Newark	Chicago	D	113	39,000	51								

Table 6 (Cont.)

Date	Flight Route: Origin	Flight Route: Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min: >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
6/25/63	Chicago	L. A.	D	219	35,000	55								
					39,000	106	25							
6/26/63	L. A.	Chicago	D	204	37,000	123	15							
6/28/63	L. A.	Chicago	D/N	197	33,000	48								
					37,000	39								
					39,000	51	20							
7/8/63	Pittsburg	Boston	D	62	25,000	29								
7/9/63	Chicago	Denver	D	116	28,000	11	11							
					31,000	24	24							
					35,000	38								
7/12/63	London	Athens	D	183	33,000	122	80	30	30	5				
7/14/63	Chicago	Portland	D/N	233	28,000	180	15							
7/16/63	Athens	Munich	D	118	29,000	87	10							
7/17/63	Seattle	L. A.	D	135	31,000	32								
					37,000	51	51	36	26	16				
7/18/63	L. A.	Chicago	N	193	31,000	11								
					37,000	132	100							
7/21/63	Seattle	L. A.	D	122	3[illegible],000	99	85	5						
7/24/63	Las Vegas	Chicago	N/D	183	37,000	61	30							
					41,000	48	30							
7/25/63	Chicago	L. A.	D	215	31,000	158	158							
7/26/63	New York	Chicago	D	95	31,000	51								
8/1/63	Chicago	S. F.	N	236	31,000	89	10							
					35,000	82	75							
					37,000	20	20							
8/1/63	S. F.	L. A.	D	54	29,000	15								

Table 6 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
8/1/63	L. A.	Chicago	D	190	33,000	139	85							
8/2/63	Chicago	Miami	D	144	37,000	84								
8/2/63	Miami	Chicago	N	153	35,000	97	45							
8/4/63	Seattle	Chicago	D	177	37,000	134	110	20	5					
8/6/63	Chicago	L. A.	D	214	39,000	148	130	10						
8/12/63	Chicago	Mex. City	D	202	31,000	112								
					39,000	41								
8/13/63	Mex. City	Chicago	D	201	31,000	17								
					37,000	137	10							
8/14/63	Chicago	Dallas	N	100	39,000	50	10							
8/14/63	Dallas	New Orl.	N	56	29,000	10								
8/15/63	New Orl.	San Juan	N/D	200	37,000	130								
8/15/63	San Juan	New Orl.	D	200	35,000	138								
8/15/63	New Orl.	Dallas	D	59	28,000	16								
8/15/63	Dallas	Chicago	D	95	28,000	45								
					33,000	13								
8/19/63	Chicago	L. A.	D	216	28,000	163	30							
8/22/63	L. A.	Chicago	D	196	37,000	130	130							
8/23/63	L. A.	Atlanta	D	227	29,000	10								
					33,000	177								
8/24/63	Atlanta	Chicago	D	115	26,000	12								
					29,000	24								

Table 7

CHRONOLOGICAL SUMMARY OF OZONE DETECTION DURING FLIGHTS OVER NORTHERN LATITUDES

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
1/3/63	Seattle	London	D/N	384	27,000	34								
					29,000	54	10							
					34,000	63	63	45						
					38,000	164	164	164	100	30				
					41,000	187	187	187	120	75				
1/5/63	London	Chicago	D/N	500	29,000	27								
					33,000	249	249	55	30					
					35,000	82	82	20						
					37,000	81	81	81	81	30				
1/18/63	S. F.	Winnipeg	D	181	29,000	145	100	40	25					
1/18/63	Winnipeg	London	N	447	34,000	135	135	135	125	70				
					39,000	262	262	262	262	262	125	30	5	
1/23/63	London	L. A.	D	667	32,000	33								
					35,000	285	155	130	115	115	55			
					39,000	140	140	75	30	15				
					40,000	145	145	145	145	110	35			
1/24/63	Seattle	Montreal	D/N	244	33,000	217	185	90	90					
1/25/63	Montreal	London	N	434	33,000	280	170	120	120	50				
1/28/63	London	Seattle	D	571	32,000	25								
					35,000	247	155	155	105	10				
					40,000	250	200	200	200	170	70	70	25	15
2/7/63	Chicago	London	N	427	33,000	53	45	45	35	25				
					37,000	304	290	290	245	145	95	45		
2/10/63	London	S. F.	D	596	31,000	92	60	30						
					32,000	70	70							
					35,000	96	55	35	10					
					36,000	280	80	80	80	35				
2/17/63	Chicago	London	N	453	33,000	145	140	20						
					34,000	25	25	25	[illegible]					
					35,000	225	225	195	80					
2/25/63	Chicago	London	N	425	33,000	31	30	30	30					
					34,000	16								
					35,000	14	15	15	15					
					37,000	307	230	215	140	40	15			

Table 7 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min ≥1 PPHM	≥3 PPHM	≥5 PPHM	≥10 PPHM	≥15 PPHM	≥20 PPHM	≥25 PPHM	≥30 PPHM
2/27/63	London	L. A.	D	643	32,000	20								
					35,000	234	175	160	150	60				
					36,000	161	161	161	161	161	80	35		
					40,000	180	160	160	160	135	70	5		
3/10/63	Chicago	London	N	438	33,000	79	60	50	50					
					37,000	302	302	270	270	190	80	10		
3/13/63	London	L. A.	D	[illegible]7	32,000	24	10							
					35,000	409	409	305	220	135	50	15		
					36,000	182	182	182	182	155	155	140	70	30
3/14/63	Chicago	Anchorage	N	367	31,000	47								
					35,000	18	18	18	18					
					36,000	165	165	165	165	165	100	85	70	10
					39,000	69	69	69	69	69	69	69	69	35
					40,000	25	25	25	25	25	25	25	25	5
3/15/63	Anchorage	New York	D/N	377	33,000	85	85	69	69	69	35	30		
					34,000	102	102	42	42	22	22	15		
					37,000	95	95	95	95	85	45	30	30	20
					38,000	45	45	45	45	45	45	45	40	40
3/20/63	Chicago	London	N	448	33,000	89	89	89	89	50				
					37,000	304	235	235	190	160	70	20	10	
3/24/63	London	S. F.	D	658	29,000	54								
					37,000	229	229	229	215	155	35			
					36,000	204	204	204	204	175	55	15		
					39,000	123	123	123	123	75	45			
3/28/63	Seattle	Anchorage	D	160	33,000	128	128	128	120	110	95	30		
3/28/63	Chicago	London	N	435	33,000	173	95	65	65	60	60			
					34,000	18	18	18	18	18	18	13	13	
					35,000	194	194	155	155	125	100	40	40	
3/29/63	Anchorage	New York	D/N	402	29,000	30	15							
					33,000	72	72	72	72	42	31			
					34,000	56	56	56	56	56	56			
					37,000	104	80	65	65	50	50	35	15	
					38,000	87	87	87	87	87	87	87	72	35
3/30/63	London	Keflavik	D	137	31,000	55								
					32,000	62	45	45	45					

Table 7 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
3/30/63	Keflavik	L. A.	D	557	35,000	285	240	195	195	15	15	15		
					36,000	210	210	210	210	135	90	25		
4/5/63	Chicago	London	N	470	33,000	51	30							
					37,000	369	369	139	240	160	85	15		
4/8/63	London	Seattle	D	569	32,000	43	35	35	25	25	10			
					35,000	247	247	120	95	80	55	20		
					40,000	225	225	225	225	225	190	150	65	15
4/19/63	Chicago	London	N	435	33,000	23	15							
					37,000	345	345	285	270	225	150	80		
4/22/63	London	Seattle	D	580	32,000	33	15	15						
					35,000	175	175	175	175	155	115			
					39,000	136	136	136	136	136	136	121	31	31
					40,000	181	181	181	181	165	165	110	45	30
4/25/63	Chicago	London	N	450	33,000	166	166	140	125	55	5			
					35,000	232	232	145	115	95	80	80	40	10
4/28/63	London	L. A.	D	662	32,000	35	10	10	10	10				
					35,000	238	238	238	238	238	165	95	10	
					36,000	147	147	110	110	110	35	20		
					39,000	187	187	187	165	125	85	25		
5/5/63	Chicago	London	D/N	411	33,000	343	290	120	120	50	20			
					34,000	18	18							
5/9/63	London	Seattle	D	563	35,000	193	193	193	193	193	163	163	23	
					36,000	299	292	292	292	292	227	147	47	
5/15/63	Seattle	Anchorage	N/D	177	39,000	121	121	121	121	121	106	95	80	
5/16/63	Anchorage	Chicago	D/N	328	29,000	34	34	25	25					
					33,000	71	71	71	71	71	71	65		
					34,000	77	77	77	77	77	77	77	25	
					37,000	105	105	105	75	60	45	40	40	30
5/17/63	Chicago	London	D/N	420	33,000	347	300	90	90	45				
					30,000	23	23							
5/23/63	London	Keflavik	D	146	28,000	109								
5/23/63	Keflavik	Seattle	D	435	35,000	285	285	265	225	155	130			
					36,000	95	95							
5/27/63	Chicago	London	D/N/D	446	33,000	352	352	50	35	5				
					30,000	28	28							

Table 7 (Cont.)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min ≥.1 PPHM	≥1 PPHM	≥5 PPHM	≥10 PPHM	≥15 PPHM	≥20 PPHM	≥25 PPHM	≥30 PPHM
5/30/63	London	Chicago	D	515	32,000	23	23							
					35,000	439	325	115	95	40				
6/6/63	Chicago	London	D/N/D	461	33,000	95	60							
					37,000	297	297	297	252	237	237	122		
6/9/63	London	L. A.	D	641	28,000	16								
					35,000	210	60	60	60	30				
					36,000	140	115	115	115	95	75	30		
					37,000	20	15							
					40,000	190	190	190	190	175	75			
6/14/63	Chicago	London	D/N/D	447	29,000	32								
					37,000	136	60	60	60					
					39,000	224	160	160	160	30				
6/18/63	London	L. A.	D	690	32,000	24	20	20	20					
					33,000	115	115	100	100	10				
					35,000	126	85	85	85	20				
					36,000	82	65	50	50	30				
					39,000	147	30							
					40,000	134	134	134	134	134	5			
6/25/63	Chicago	London	D/N/D	444	30,000	22	22	22	22	10				
					33,000	373	225	120	90	40				
6/28/63	London	Keflavik	D	158	31,000	54								
					32,000	55	35	5	5					
6/28/63	Keflavik	L. A.	D	533	35,000	106	55	55	55	40	40			
					36,000	187	187	187	162	147	132			
					39,000	175	175	175	175	150	60			
7/8/63	Boston	London	N/D	365	31,000	65	5							
					35,000	228	45	5	5					
7/8/63	Chicago	London	D/N/D	445	29,000	[illegible]	13							
					30,000	[illegible]	13	13	13					
					33,000	129	129	65	65	55	50	50		
					34,000	32	32	32	32	32	32			
					35,000	210	210	140	125	75	60	20		
7/20/63	Anchorage	Seattle	N	170	37,000	124	124	124	124	124	65			
7/30/63	Chicago	Anchorage	D	350	35,000	51								
					36,000	143	120	120	120	120	55	[illegible]		
					39,000	105	105	105	105	75	40	10		

Table 7 (Cont.)

Date	Flight Route: Origin	Flight Route: Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min: ≥1 PPHM	≥3 PPHM	≥5 PPHM	≥10 PPHM	≥15 PPHM	≥20 PPHM	≥25 PPHM	≥30 PPHM
8/3/63	Anchorage	Seattle	N	175	37,000	139	15	15	5					
8/16/63	Chicago	London	D/N/D	419	33,000	370	330	155	150	30				
8/21/63	London	Keflavik	D	151	32,000	111	5							
8/21/63	Keflavik	L. A.	D	526	31,000	81	15							
					35,000	169	90	25	15	5				
					36,000	219	140	125	95	10				

Table 8

CHRONOLOGICAL SUMMARY OF OZONE DETECTION DURING FLIGHTS OVER POLAR LATITUDES

Date	Flight Route		Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min							
	Origin	Destination					>1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM	>25 PPHM	>30 PPHM
7/20/63	Copenhagen	Anchorage	D	501	29,000	183	125	115	105	75	75	50		
					32,000	103	103	103	103	103	60	45		
					36,000	129	129	129	129	129	129	129	70	
					37,000	37	37	37	37	37	37	37	37	
7/31/63	Anchorage	Copenhagen	D	505	23,000	91	60	50	50	30				
					29,000	130	90	50	45	15				
					33,000	39	39	35	30	20				
					34,000	126	126	80	70	25				
					38,000	73	73	65	40	15				
8/3/63	Copenhagen	Anchorage	D	500	29,000	68	68	15	5					
					32,000	172	172	60	30	15				
					36,000	60	60	60	60	60	60	55		
					37,000	149	149	149	149	149	130	30		

Table 9

CHRONOLOGICAL SUMMARY OF OZONE DETECTION DATA OBTAINED ON CONTRACT NO. FA 2680
(December 19, 1961, through April 30, 1962)

Date	Flight Route Origin	Flight Route Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min >1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM
2/6/62	S. F.	L. A.	N	75	27,000	10						
2/6/62	L. A.	S. F.	N	75	27,000	10						
2/7/62	S. F.	Chicago	D	225	28,000	30	20					
					33,000	45	45					
					37,000	120	100	70	20	20	5	
2/16/62	Honolulu	L. A.	D/N	285	29,000	240						
2/17/62	L. A.	New York	N	270	29,000	105	60					
					31,000	135						
2/17/62	New York	Chicago	D	120	28,000	100						
2/25/62	Chicago	L. A.	N	240	28,000	180						
					31,000	30						
2/25/62	L. A.	Honolulu	N	320	28,000	140						
					31,000	160						
2/26/62	Honolulu	L. A.	D/N	260	37,000	210	45	25	10			
2/27/62	L. A.	Cleveland (New York)	N/D	350	33,000	120	120	75	75			
					37,000	180	180					
2/27/62	Cleveland	New York	D	65	27,000	45						
2/27/62	New York	S. F.	D	300	31,000	150	45					
					37,000	45	45	45	45	45		
					39,000	120	120	120	120	120		
2/27/62	S. F.	Seattle	N	100	35,000	55	45	45				
2/28/62	Seattle	Chicago	D	195	33,000	145	105					
3/5/62	Chicago	Phila.	D	120	35,000	95	60	30	10			
3/5/62	Phila.	Chicago	N	120	33,000	95	55	45	45			
3/18/62	Chicago	L. A.	N	240	28,000	200	120	15				
3/19/62	L. A.	New York	N	255	37,000	195	195	195	110	75		
3/19/62	New York	S. F.	D	325	28,000	275	250					
3/19/62	S. F.	Honolulu	D	295	37,000	255	120					

Table 9 (Cont.)

Date	Origin	Destination	Time of Day	Flight Time, min	Altitude, ft	Time at Altitude, min	Time Ozone Detected, min					
							>1 PPHM	>3 PPHM	>5 PPHM	>10 PPHM	>15 PPHM	>20 PPHM
3/20/62	Honolulu	S. F.	N	275	29,000	225	160	40	30			
3/20/62	S. F.	Chicago	D	210	29,000	85	5					
					33,000	110	80	50	50	15		
3/20/62	Chicago	Phila.	D	135	37,000	75	35	10				
3/20/62	Phila.	Chicago	N	145	31,000	75						
3/27/62	Chicago	L. A.	N	220	31,000	175	175					
3/27/62	L. A.	Baltimore	D	255	29,000	120	120					
					37,000	95	95	20	20	20		
3/27/62	Baltimore	L. A.	D/N	300	35,000	170	165	45	20	5		
					39,000	85	85	85	55			
3/28/62	L. A.	Chicago	N	200	37,000	165	165	60	50			
4/12/62	Chicago	Baltimore	D	90	31,000	35	35					
4/12/62	Baltimore	Chicago	D/N	120	28,000	60	55	5	5			
4/12/62	Chicago	Denver	N	115	33,000	75	75	30	30	30		
4/13/62	Denver	Chicago	D	110	29,000	65	65					
4/13/62	Chicago	Phila.	D	90	27,000	15	10	10				
					33,000	30	30	30	30	30	30	10
4/13/62	Phila.	Chicago	D/N	95	31,000	55	55	55	55	55	55	
4/15/62	Chicago	Baltimore	N	80	27,000	45	45	5				
4/16/62	Baltimore	Chicago	D	90	28,000	55	55	15	5			